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On relation between radar super-refraction echoes and height of ducting layers along west coast of India

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सार — बम्बई स्थित एस० बैंड रेडार का प्रयोग करके अरब सागर के पार और भारत के पश्चिमी तट के साथ-साथ प्रेक्षित सूक्ष्म तरंगों के असामान्य संचरण का अध्ययन इस शोध-पत्र मे प्रस्तुत किया गया है। अरब प्रायद्वीप की अत्यंतदूरस्थ प्रतिध्वनियां पीपीआई स्कोप में देखी गई है। रेडियों सोन्दे/रेडियों विंड एकक, बम्बई के रेडियों सोन्दे आंकड़ों का प्रयोग करते हुए मौसम वैज्ञानिक स्थितियों से संबंधित असामान्य संचरणों में विभिन्नता का अध्ययन किया गया है। यह देखा गया है कि जब भी उत्थित वाहिनी विद्यमान होती है तब अतिअपवर्तन प्रतिध्वनियां भी पीपी आई स्कोप पर विद्यमान होती है। भू-प्रतिध्वनियों में वृद्धि प्रत्यक्ष रुप से इन वाहिनी सतहों की ऊंचाई में कमी से संबंधित दिखाई देती है।

ABSTRACT. The paper presents a study of abnormal propagation of microwaves observed along the west coast of India and across Arabian Sea using a S-band radar located at Bombay. Very distant echoes of Arabian Peninsula has been seen on PPI scope. The variation in the abnormal propagation has been studied in relation to meteorological conditions using radiosonde data of RS/RW unit, Bombay. It is seen that whenever elevated ducts are present, super-refraction echoes are also present on PPI scope. The increase in ground echoes is seen to be directly related to the decrease in the height of these ducting layers.

1. Introduction

Propagation of VHF radio waves far beyond the normal radio horizon is called abnormal propagation and has been observed over every region of the world. Many workers have studied this phenomena using X-band and S- band radars in which the effect is seen by the increase of ground clutter.

Many workers have tried to relate the abnormal propagation to meteorological conditions. Using radiosonde data, refractive index gradients have been calculated to study the ducting conditions leading super-refraction. Whenever a duct forms, microwaves emitted by radar get trapped in the duct and travels exceedingly long distance thereby producing echoes of objects hundreds of kilometres away from the radar and well beyond normal radio horizon.

Rajagopalan and Raghavan (1980) in a study of tropospheric propagation using S-band radar at Madras have concluded that quantitative calculation of super-refraction conditions leading to increase/decrease of echoes on scope are not possible with the coarse radiosonde data. Chatterjee and Mathur (1982) studied the occurrence of elevated radio ducts along the east and west coasts during the months June to September 1974 using the radiosonde data. Their study shows that range of refractivity gradients over west coast vary from — 159N to — 380N units, which makes ducting conditions to occur. These ducts are usually elevated with their height varying from 500 metres to 2-3 km.

The present study deals with radar observations of super-refraction using S-band radar (Peak power 1 Magawatt, Pulse width 2 μ sec, Frequency 2800 MHz, Beamwidth 1.8° conical and Max. range 500 km) at Bombay during pre-monsoon months April-May 1984. Cases of unusual ground echoes or anomalous propagation echoes (AP echoes) have been selected and an attempt has been made to relate them to refractivity gradients as revealed by 0530 IST and 1730 IST radiosonde data of Bombay.

2. Data

2.1 *Radar observations*

The S-band radar is in operation at Bombay since 1976 for tracking of cyclones. Due to super-refraction some times echoes of objects located several hundreds kilometres are seen in the PPI scope. These are essentially multiple time around echoes, the strength of which varies as a function of changing refractive index distribution. The radar energy instead of dispersing in space inversely as a square of distance, gets trapped in ducts and travels hundreds of kilometres and gets scattered back by objects there with sufficient energy travelling through the same duct to be discernible by radar and appear as echoes.

Figs. 1 to 6 are radar PPI photographs showing echoes due to anomalous propagation during April-May 1984. As may be seen, echoes in NW direction at a distance of 300 km is Arabian Peninsula which is actually 1400 km from Bombay. Similarly in the N-S direction, the western coast is seen right up to 500 km which is not possible in normal conditions due to earth's curvature. Maximum amount of echoes are seen on 1730 IST of 24th April.

It may be noted that there is large variation in the extent of echoes from observation to observation. More echoes are seen in the evening as compared to morning. This is understandable since sharp discontinuities in temperature and humidity are not possible in the morning hours due to convective mixing which inhibits duct formation at lower heights as compared to evening hours when sea breeze sets in off-setting the convective mixing.

2.2. *Radiosonde data*

To study the variation in propagation conditions, upper air radiosonde data of Bombay RS/RW station has been used to calculate refractivity profiles. As is known, the path followed by radio ray in the atmosphere is dependent upon the vertical gradient of the atmospheric radio refractivity. The radio refractivity gradient has to be equal or more than — 157 N unit/km for the ducting conditions to occur.

The radio refractivity 'N' is given by

$$N=(n-1)\times 10^{-6}=77.6\,PT^{-1}+3.73\times 10^{-5}\,eT^{-2}$$

where, n = Atmospheric radio refractive index,

P = Pressure in millibars,

T = Temperature in °A,

e = Vapour pressure of moisture in millibars,

also $\ln e = 21.64 - 5418\,T_d^{-1}$

where, T_d = Dew point in °A.

From the radiosonde data of 0530 IST and 1730 IST radio-refractivity values for the standard millibaric levels and the levels of significant changes of T and T_d up to 700 mb have been calculated and refractivity profiles prepared. These are plotted and shown in Figs. 7 (a & b). Table 1 tabulates the thickness of layers in which $\triangle N/\triangle H$ is more than—157 N units. Heights of bases of these ducts are also given in the table. These have been calculated from the curves of Figs. 7(a & b).

Fig. 8 is a plot of the thickness of duct nearest to ground on different days. Fig. 9 shows the variation of the height of the lowest layer of duct on different days.

TABLE 1

Radio-Refractive Index gradient in the ducting layers
(Ducting layers, thickness and height)

Date (1984)	Time (UTC)	Ht. of base of duct (m)	'N' at base	Thickness of layer (m)	'N' at top	Gradient $-\frac{dN}{dH}$ (N unit/km)
22 Apr	00	260	367	202	290	381
22 Apr	00	2300	247	238	201	193
22 Apr	12	54	337	206	308	141
22 Apr	12	2360	259	183	202	311
24 Apr	00	43	339	207	303	174
24 Apr	12	18	350	132	308	318
26 Apr	00	No ducting condition				
26 Apr	12	486	362	487	280	168
26 Apr	12	1190	322	281	248	263
10 May	00	780	350	207	288	300
10 May	00	1280	251	156	223	244
10 May	12	470	367	509	258	214
11 May	00	800	349	681	257	135
11 May	00	462	305	238	268	155
15 May	00	880	350	576	256	163
15 May	12	550	334	250	265	276
19 May	00	400	376	571	291	149
19 May	12	560	352	396	273	200

3. Discussion

The radio-refractivity profiles in Figs. 7 (a & b) appear to be similar. However, an examination of Table 1 shows that except for 0530 IST of 26th April, two ducting layers are present in all the observations. It is seen that the variation of—$\triangle N/\triangle H$/km is from—135N units to—381N units and the height of the base of the ducting layer is not uniform. At 1730 IST of 24 April, the base of the 1st layer is only 18 metres from the surface, *i.e.*, practically a surface duct is present on this day. Since the duct lowest to the surface is likely to trap the maximum energy radiated from the radar antenna (height of radar antenna 20 m from ground), we will examine the thickness of the lowest ducting layer and its height to see whether it can be related to variation in extent of echoes seen in PPI scope.

Fig. 8 is a plot of thickness of the lowest ducting layer on different days. Since on 26th morning, the refractivity gradient was never more than —157 N unit the ducting layer was absent. It is seen that on other days the variation in thickness of lowest is between 300 and 400 m except for 1730 IST of 26th when it was 487 m. Therefore, it appears that variation in thickness of duct has not appreciable effect on the variation in extent of echoes.

Fig. 9 shows the variation of the height of the base of the lowest ducting layer. It is seen, the ducting layer, when present in the morning, has descended down in the evening. A comparison of this with the PPI photographs show that whenever the ducting layer descends, there is a marked increase in the ground echoes in the radar as seen at different times of radar observation on the same day. On 24th evening it is almost at the surface and maximum echoes are seen on the radar scope. Since the antenna height is 20 metres from ground, maximum energy would be trapped when the duct layer height is around the level of antenna, *i.e.*, 20 metres and maximum ground returns would be seen on this day. At 0530 IST of 26th April when no ducting layer is present, ground echoes are also absent. Further it is also seen that

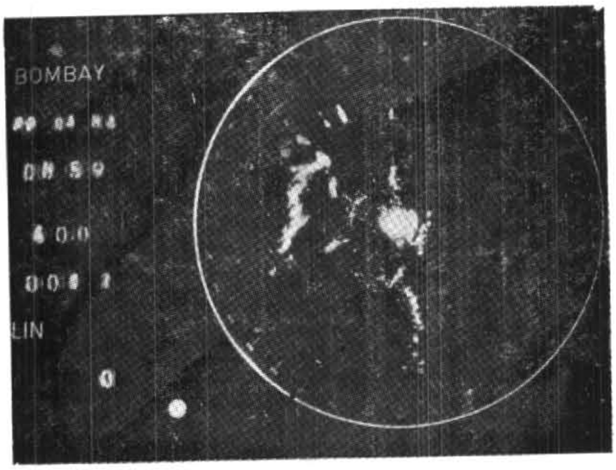


Fig. 1. Radar PPI photograph at 0859 UTC of 22 April 1984 showng west coast line and part of African coast due to super-refraction. Range markers are at 100 km interval

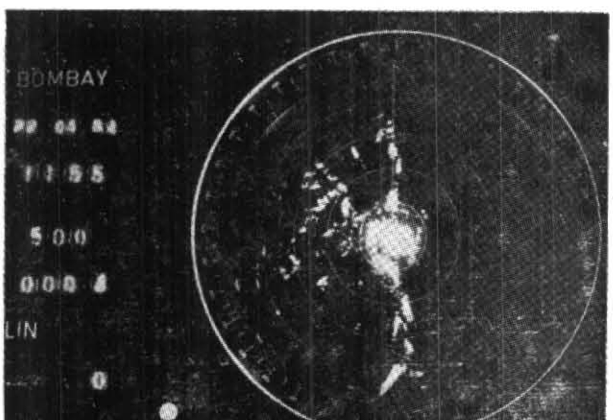


Fig. 2. Radar PPI photograph at 1155 UTC of 22 April 1984 showing echoes due to super-refraction. Range markers are at 100 km interval

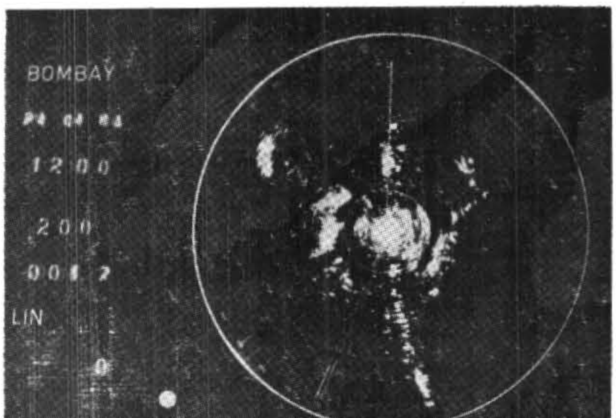


Fig. 3. Radar PPI photograph at 1200 UTC of 24 April 1984 showing echoes due to super-refraction all around. Range markers are at 50 km interval

Fig. 4. Radar PPI photograph at 0300 UTC of 19 May 1984 displaying African coast as a multiple time round echo. Range markers are at 100 km interval

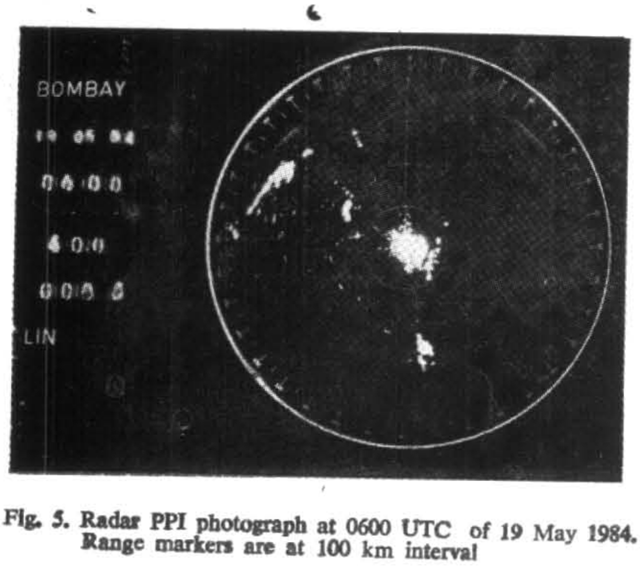


Fig. 5. Radar PPI photograph at 0600 UTC of 19 May 1984. Range markers are at 100 km interval

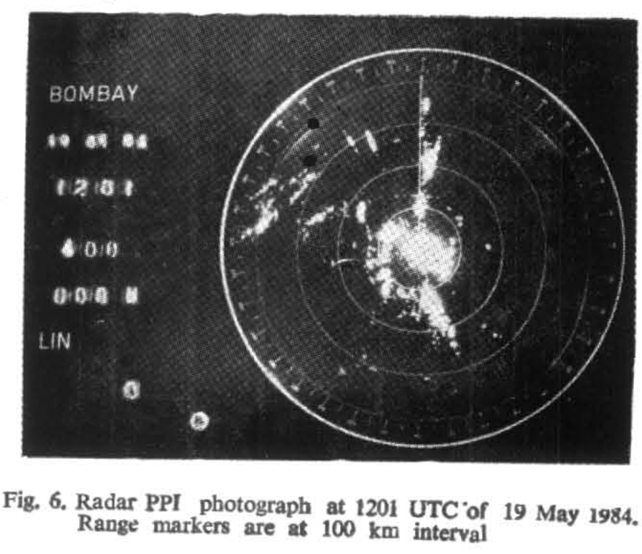
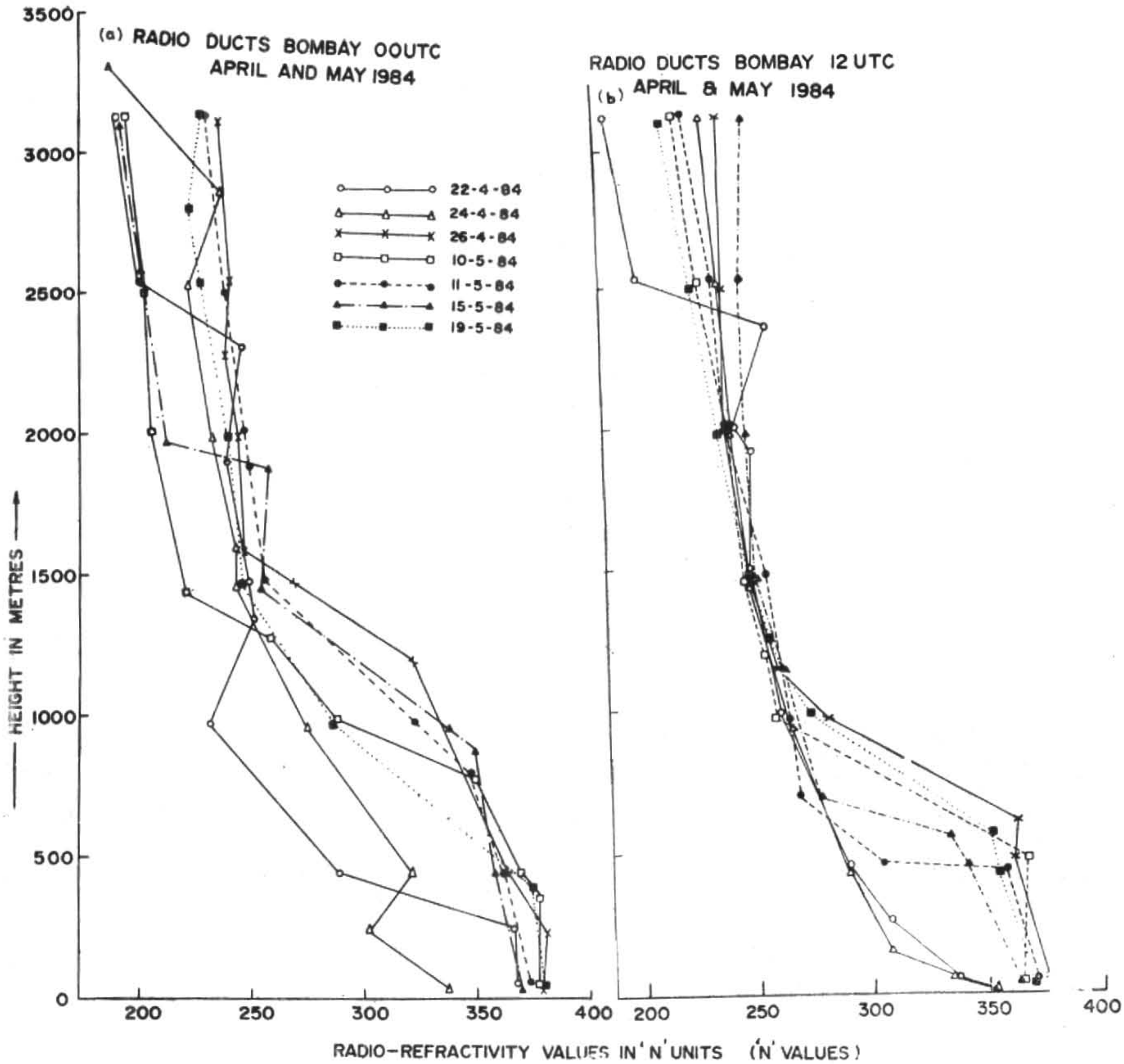


Fig. 6. Radar PPI photograph at 1201 UTC of 19 May 1984. Range markers are at 100 km interval



Figs. 7(a & b). 'N' value *versus* height curves for : (a) 00 UTC & (b) 12 UTC

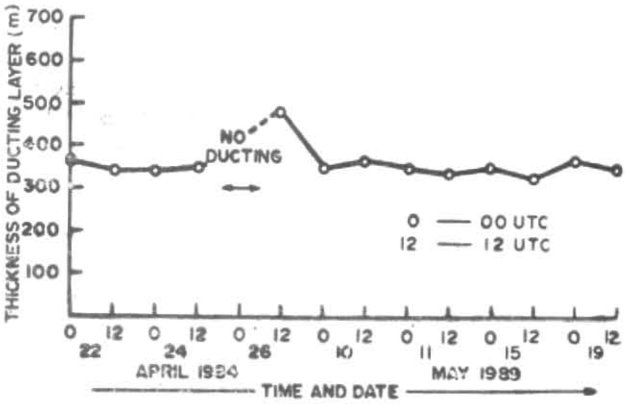


Fig. 8. Curves showing thickness of duct on different days

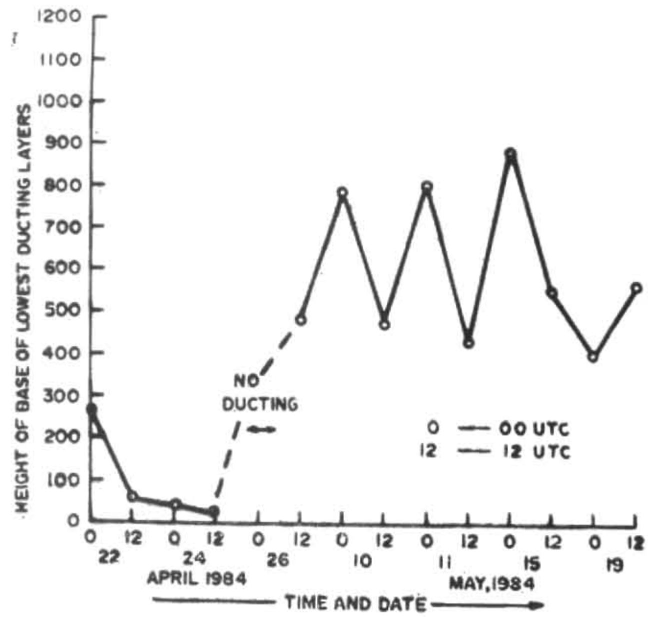


Fig. 9. Curve showing height of base of lowest ducting layer on different days

variation in the value of $-dN/dH$ in the ducting layer is less important than the variation in the height of the base of the duct as is evident from the 00 UTC observation of 22 and 24 April 1984 12 UTC when $-dN/dH$ on these days at these hours was 381 and 318 respectively.

4. Conclusion

A new concept of the relation between the height of the ducting layers and extent of ground echoes has been established in this study. The variation in the thickness of the lowest ducting layer has no appreciable effect on the variation of the extent of echoes. Super-refraction is more pronounced when the height of the lowest ducting layer decreases. The height of the ducting layer generally decreases as the day advances leading to increase in super-refraction echoes. The reduction in height of the ducting layer is due to the onset of sea breeze in the after-noon.

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